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Dietary factors and the risk of squamous cell esophageal cancer among black and white men in the United States*

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Objectives: To investigate dietary factors for squamous cell esophageal cancer and whether these factors may contribute to the five-fold higher incidence of this cancer in the black versus white population of the United States.
Methods: Data from a food frequency questionnaire were analyzed for 114 white men and 219 black men with squamous cell esophageal cancer, and 681 white and 557 black male controls from three areas of the United States who participated in a population-based case-control study of esophageal cancer.
Results: Protective effects were associated with intake of raw fruits and vegetables (odds ratio for high versus low consumers = 0.3 in both white and black men) and use of vitamin supplements (especially vitamin C; odds ratio for high versus low consumers = 0.4 in both races), with the frequency of consumption of raw fruits and vegetables and vitamin supplements being greater for white than black controls. In addition, elevated risks were associated with high versus low intake of red meat (OR = 2.7 for blacks and 1.5 for whites) and processed meat (OR = 1.6 for blacks and 1.7 for whites), with the levels of consumption being greater for black than white controls.
Conclusions: In the United States, these dietary factors may contribute in part to the much higher incidence of squamous cell esophageal cancer among black compared to white men. *Cancer Causes and Control*, 1998, 9, 467-474

Key words: Case-control studies, diet, esophageal neoplasms, raw fruit, raw vegetables.

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Introduction

The incidence of esophageal cancer is more than three times greater among US black men than white men due to the five-fold higher incidence rate of squamous cell esophageal cancer among black (16.8 per 100 000) than white men (3.0 per 100 000).[1] To evaluate reasons for this racial disparity, we conducted a population-based case-control study of squamous cell esophageal cancer among white and black men in three areas of the United States. A previous analysis found that heavy drinking and smoking accounted for over 85 percent of squamous cell esophageal cancer in both blacks and whites, and for 94 percent of the excess in incidence rates among blacks. However, reasons for the higher levels of risk observed among black versus white men exposed to similar amounts of alcohol and tobacco are not known.[2] One possibility is that other environmental determinants such as nutritional factors that vary among whites and blacks interact with alcohol and/or tobacco to modify risks. This paper evaluates the role of dietary factors in the black/white differential for squamous cell esophageal cancer, including possible modification of risks associated with alcohol or tobacco.

Materials and methods

Methods for case/control selection have been published in detail elsewhere.[2] In brief, eligible cases were black and white male residents of Atlanta, Detroit, and New Jersey aged 30-79, diagnosed with histologically confirmed esophageal cancer from August 1, 1986 through April 30, 1989. Controls were selected to be similar to the expected age, race, gender, and area distribution of the cases. Controls aged 30-64 years were selected using a random-digit dialing (RDD) technique,[3] whereas controls aged 65-79 years were randomly chosen from computerized listings of Medicare registrants provided by the Health Care Financing Administration (HCFA).

In-person interviews lasting approximately 60 minutes were conducted by trained interviewers, usually in the homes of the subjects. Detailed information was obtained on socio-demographic factors, use of alcohol and tobacco, usual occupation, medical and dental history, and usual adult diet. Interviews were completed for 68 percent of the cases and 76 percent of the controls, with similar proportions for whites and blacks. Reasons for non-response included death (19 percent cases; 1 percent controls), illness (8 percent cases; 4 percent controls), and refusal (4 percent cases, 16 percent controls). No proxy interviews with next of kin were conducted.

Dietary analyses were based on 114 white and 219 black cases and 681 white and 557 black controls after excluding 40 cases (10 white, 30 black) and 126 controls (69 white, 57 black) who answered fewer than 95 percent of the individual food items in the questionnaire, or whose responses were considered to be unreliable (e.g., individuals with extremely high or low values for total amount of food consumed), or who had missing data on smoking or drinking.

A detailed description of the dietary assessment methodology is provided elsewhere.[4] Briefly, subjects were asked to recall their usual frequency, excluding the past five years, of consumption of 60 specific food items (e.g., grapefruit, green peas, chicken) or groups of similar food items (e.g., spaghetti, macaroni, or noodles). To evaluate dietary factors, individual foods were categorized into food groups as outlined in the Appendix. Nutrient intakes were estimated based on the frequency of consumption of each food item and the nutrient content of an average serving for males obtained from the National Health and Nutrition Examination Survey (NHANES II) nutrient data base.[5] Four consumption categories ranging from low to high were created for each food group and selected nutrients by dividing the frequency distribution for the controls into approximate quartiles. Subjects were also asked about their use of vitamin supplements five years before the interview. Body mass index (BMI, kg/m^2) was determined from reported usual adult weight and height.

Data were analyzed using unconditional logistic regression.[6] Odds ratios (OR) and 95 percent confidence intervals (CI) were obtained using the BMDPLR procedure.[7] All models included the variables of age at diagnosis/interview, geographic area, number of years smoked cigarettes (0, 1–29, 30–39, $\geq$40), a stronger risk factor in these data than number of cigarettes smoked, and number of drinks of alcoholic beverage per week (0–7, 8–14, 15–35, 36–84, $\geq$85). Addition of income and education as potential confounders did not substantially alter the ORs. Thus these variables were not included in the final logistic models. Energy adjustment was accomplished by including a term for calories (excluding those from alcohol) in quartiles. To test for linear trend categorical variables were entered as continuous variables in the logistic models, with each level represented by the median value of that category in the control group. To assess whether diet modified the interaction of race with combined exposure to drinking and smoking, we compared the likelihood ratio test statistic for the significance of the interaction term in logistic models with and without selected dietary variables.

Results

A reduced risk of squamous cell esophageal cancer was seen for men in the highest compared to the lowest quartile of BMI in both races (OR = 0.8, 95 percent CI = 0.5–1.6, for whites; OR = 0.4, 95 percent CI = 0.2–0.6, for blacks), although a significant negative trend in risk with increasing BMI was seen only for black men ($p < .001$) (Table 1). The percentage of white (40 percent) and black (44 percent) cases in the lowest quartile of BMI was similar, but a greater percentage of whites (26 percent) than blacks (12 percent) was in the highest quartile. No significant trends were associated with intake of total calories from food, although risks for white and black men were nonsignificantly elevated at the higher levels of caloric intake. Adjustment for other dietary factors (e.g., consumption of raw fruits and vegetables or red meat) did not affect the risk estimates.

Adjusted ORs for the major food groups and their subcategories are presented in Table 2. No significant associations were observed for dairy products, bread/grains/cereal, or meat/poultry/fish for either white or black men. Among black men, significant trends of increased risk with increased consumption were seen for eggs, red meat, liver, and processed meats. The ORs for the highest versus lowest quartiles were: 2.5, 95 percent CI = 1.4–4.6, for eggs; 2.7, 95 percent CI = 1.3–5.5, for red meat; 1.5, 95 percent CI = 0.9–2.5, for liver; and 1.6, 95 percent CI = 0.8–3.1, for processed meat. Among white men, risks were also raised for heavier consumers of eggs (OR = 1.4, 95 percent CI = 0.6–2.9), red meat (OR = 1.5, 95 percent CI = 0.6–3.5), and processed meat (OR = 1.7, 95 percent CI = 0.8–3.7), but not liver. Among controls, the percentage of men reporting high consumption of processed meats (at least 8.5 servings per week) was substantially greater for blacks (29 percent) than for whites (19 percent), whereas the percentage reporting high consumption of red meat (more than 12.8 servings per week) was only slightly greater for blacks (27 percent) than for whites (23 percent).

Risks associated with fruit intake were reduced in the highest versus lowest quartiles for both whites (OR = 0.5, 95 percent CI = 0.2–1.0) and blacks (OR = 0.4, 95 percent CI = 0.2–0.7), with significant negative trends with increased consumption. This pattern was noted for various subcategories of fruits with the exception of citrus fruits. A protective effect was associated with increased consumption of all vegetables, and most subcategories, among white men but not among black men. For raw vegetables, a reduced risk was associated with high versus low consumption of raw vegetables in both races (OR = 0.4, 95 percent CI = 0.2–0.8 for whites and blacks), with significant negative trends. Among controls, the percentage who reported eating raw vegetables (i.e., tossed salad, coleslaw, tomatoes) at least once a day was considerably higher in white men (30 percent) than in black men (18 percent). For raw fruits and vegetables, both races had a significant gradient of decreased risk with increased consumption. At the highest level of intake (more than 18 servings per week), both white men (OR = 0.3, 95 percent CI = 0.2–0.7) and black men (OR = 0.3, 95 percent CI = 0.2–0.6) experienced significant 70 percent reductions in risk when compared to those with the lowest intake (seven or fewer servings per week). Adjustment for other dietary factors did not affect the risk estimates.

Table 3 shows adjusted ORs for consumption of specific nutrients and other dietary constituents. No

Table 1. ORs for squamous cell esophageal cancer in black and white men according to dietary factors

Factor	White				Black			
	No. of cases	No. of controls	OR	95% CI	No. of cases	No. of controls	OR	95% CI
BMI, kg/m^2 [a]								
<23.2	46	174	1.0	-	95	137	1.0	-
23.2–25.0	18	170	0.3	0.2-0.6	68	141	0.7	0.4-1.1
25.1–27.1	20	183	0.6	0.3-1.1	28	128	0.4	0.2-0.6
⩾27.2	30	151	0.8	0.5-1.6	27	151	0.4	0.2-0.6
			$P = 0.71$				$p < 0.001$	
Total calories from food[b]								
<1363	17	157	1.0	-	44	154	1.0	-
1363–1756	24	176	1.2	0.6-2.6	48	133	1.2	0.7-2.0
1757–2167	38	191	1.6	0.8-3.3	51	119	1.5	0.8-2.6
⩾2168	35	157	1.5	0.8-3.1	76	151	1.3	0.8-2.2
			$P = 0.21$				$p = 0.32$	

[a] Estimates are adjusted for age, area, smoking, alcohol, and food calories.
[b] Estimates are adjusted for age, area, smoking, and alcohol.

Table 2. ORs for squamous cell carcinoma of the esophagus in white and black men according to consumption level of selected foods and food groups[a]

Food group	White					Black				
	Quartiles of consumption					Quartiles of consumption				
	Low		High			Low		High		
	1	2	3	4	P	1	2	3	4	P
Dairy products	1.0	1.8	0.9	1.0	0.46	1.0	0.7	1.2	0.6	0.09
Eggs	1.0	1.2	1.7	1.4	0.58	1.0	1.3	1.0	2.5[b]	0.001
Bread, grains, and cereal	1.0	1.1	1.3	1.3	0.46	1.0	0.9	1.4	1.5	0.09
Meat, poultry, and fish	1.0	1.2	1.4	1.2	0.68	1.0	1.3	1.3	1.4	0.36
Poultry and fish	1.0	1.0	1.0	0.7	0.34	1.0	0.6	0.7	0.6	0.45
Red meat	1.0	1.5	1.3	1.5	0.56	1.0	2.4[b]	2.4[b]	2.7[b]	0.03
Liver	1.0	0.6	0.6	0.8	0.87	1.0	0.8	0.9	1.5	0.02
Processed meats	1.0	1.5	1.1	1.7	0.25	1.0	0.7	1.6	1.6	0.04
Fruits	1.0	0.9	0.7	0.5	0.04	1.0	1.0	0.8	0.4[b]	0.001
Citrus fruits	1.0	0.6	0.9	0.8	0.91	1.0	1.0	0.9	0.8	0.55
Noncitrus	1.0	0.9	0.5	0.5	0.048	1.0	1.1	0.9	0.5[b]	0.007
Apples/pears/bananas	1.0	1.2	0.5	0.5	0.01	1.0	0.8	0.8	0.4[b]	0.003
Raw	1.0	0.8	0.7	0.5	0.07	1.0	0.8	0.8	0.6	0.01
Vegetables	1.0	0.4[b]	0.6	0.4[b]	0.06	1.0	1.6	1.3	1.0	0.89
Cruciferous/Vitamin C-rich	1.0	0.6	0.8	0.7	0.33	1.0	0.8	0.6	0.8	0.50
Dark green	1.0	0.6	0.6	0.4	0.04	1.0	0.7	1.4	1.0	0.64
Dark yellow	1.0	0.4[b]	0.6	0.4[b]	0.01	1.0	0.8	0.8	0.7	0.41
Legumes	1.0	0.8	0.8	0.6	0.21	1.0	1.1	1.6	0.7	0.28
Raw	1.0	0.5[b]	0.5[b]	0.4[b]	0.03	1.0	1.0	0.6	0.4[b]	0.005
Raw fruits and vegetables	1.0	0.6	0.7	0.3[b]	0.008	1.0	0.6	0.5[b]	0.3[b]	0.001

[a] Estimates are adjusted for age, area, smoking, alcohol, and food calories.
[b] Confidence interval does not include 1.0.

significant associations were observed for protein, total fat, saturated fat, and total carbohydrates, and no significant trends appeared when adjustment for calories was removed from the logistic models. For black but not white men, there was a significant positive gradient in risk with consumption of cholesterol, and a nonsignificant positive gradient with consumption of iron and vitamin A from animal sources.

ORs were reduced with increased intake of total fiber and fiber from fruit in both races, as well as fiber from vegetables in white men only. Significant reductions in risks for the highest versus lowest quartile of consumption were seen for total fiber (OR = 0.3, 95 percent CI = 0.1–0.8) and fiber from vegetables (OR = 0.4, 95 percent CI = 0.2–1.0) in white men, and for fiber from fruit in black men (OR = 0.5, 95 percent CI = 0.3–0.9). In contrast, both black and white men had elevated risks (OR = 1.8) associated with high intake levels of fiber from grain.

No consistent pattern of risk was noted for total vitamin A intake in either white or black men. However, reduced risks were observed in whites consuming high levels of vitamin A from vegetables (OR = 0.5, 95 percent CI = 0.2–1.0) and in blacks consuming high levels of vitamin A from fruit (OR = 0.5, 95 percent CI = 0.3–0.9). A similar pattern was seen for subcategories of vitamin C, but no consistent associations were noted for B-vitamins or calcium. When fruit and vegetable food groups as well as dietary vitamin A, vitamin C, and fiber were adjusted separately for the effects of one another, ORs for the food groups were unchanged, while protective effects for the dietary constituents/nutrients were slightly attenuated (data not shown).

The risks associated with use of vitamin supplements are presented in Table 4. Use of any vitamin supplement was reported by 25 percent of cases and 35 percent of controls (OR = 0.6, whites and OR = 0.8, blacks; nonsignificant). The decreased risk was most pronounced for vitamin C, both in whites (OR = 0.4, 95 percent CI = 0.2–0.9) and in blacks (OR = 0.4, 95 percent CI = 0.2–1.1). The proportion of vitamin supplement users was slightly higher for white controls (39 percent) than for black controls (34 percent), but vitamin C use was twice as high in whites (18 percent) compared to blacks (9 percent). A variable combining intake of vitamin C from supplements and dietary sources yielded lower risks than those for the dietary variable alone. Risks in whites were 1.0, 0.8, 0.8, and 0.4 (p for trend = 0.23), while risks in blacks were 1.0, 1.0, 0.5, and 0.5 (p for trend = 0.04) for low to high quartiles of total vitamin C consumption.

Table 3. ORs for squamous cell carcinoma of the esophagus in white and black men according to intake of specific nutrients or other dietary constituents[a]

Nutrient/dietary constituent	White					Black				
	Quartiles of consumption					Quartiles of consumption				
	Low			High		Low			High	
	1	2	3	4	P	1	2	3	4	P
Protein	1.0	0.6	0.8	0.4	0.14	1.0	0.8	0.9	0.9	0.82
Total fat	1.0	1.5	1.0	0.9	0.75	1.0	0.8	1.2	0.8	0.67
Saturated fat	1.0	1.9	1.0	0.6	0.13	1.0	1.1	1.5	0.9	0.80
Cholesterol	1.0	1.2	1.5	1.2	0.87	1.0	0.6	1.2	2.0	0.003
Carbohydrates	1.0	0.8	0.9	0.8	0.79	1.0	0.5	0.4	0.7	0.90
Fiber	1.0	0.5[b]	0.4[b]	0.3[b]	0.02	1.0	1.0	0.5	0.6	0.15
From fruit	1.0	0.9	0.9	0.5	0.05	1.0	1.3	1.0	0.5[b]	0.01
From vegetables	1.0	0.4[b]	0.6	0.4[b]	0.13	1.0	1.2	1.2	1.0	0.82
From grain	1.0	1.9	1.1	1.8	0.44	1.0	1.2	1.2	1.8	0.07
Vitamin A	1.0	1.0	0.9	0.6	0.18	1.0	1.2	1.0	1.4	0.48
From fruit	1.0	1.2	0.8	1.2	0.64	1.0	0.7	0.5[b]	0.5[b]	0.047
From vegetables	1.0	0.5[b]	0.6	0.5[b]	0.06	1.0	1.5	1.2	1.3	0.61
From animal sources	1.0	1.8	0.8	1.1	0.60	1.0	1.3	1.4	1.8	0.07
Vitamin C	1.0	1.2	0.8	0.7	0.24	1.0	0.6	0.7	0.5[b]	0.07
From fruit	1.0	1.0	0.7	0.9	0.67	1.0	0.8	0.9	0.5[b]	0.04
From vegetables	1.0	0.4[b]	0.5[b]	0.5	0.18	1.0	1.4	1.4	1.3	0.58
B-vitamins										
Niacin	1.0	0.9	1.0	1.3	0.37	1.0	0.9	0.9	1.0	0.90
Riboflavin	1.0	1.7	2.8[b]	0.9	0.42	1.0	1.2	1.0	1.2	0.67
Thiamine	1.0	0.7	1.6	1.3	0.47	1.0	1.2	0.9	0.9	0.83
Folate	1.0	0.5	0.6	0.7	0.63	1.0	1.3	0.8	1.1	0.85
Iron	1.0	0.6	0.9	0.7	0.79	1.0	1.2	1.6	2.2	0.11
Calcium	1.0	1.6	1.1	0.9	0.39	1.0	0.7	0.6	0.7	0.44

[a] Estimates are adjusted for age, area, smoking, alcohol, and food calories.
[b] Confidence interval does not include 1.0.

Stratification of dietary variables by level of alcohol or tobacco use yielded no significant variation in the risk estimates. For example, among blacks and whites combined, the OR for the highest versus lowest consumption level of raw fruits and vegetables was 0.2 (95 percent CI = 0.1-0.3) in the top category of smoking and drinking (20 or more cigarettes per day and more than 14 drinks per week), and 0.5 (95 percent CI = 0.1–2.2) in the bottom category (less than 20 cigarettes per day and 14 or fewer drinks per week). The small number of cases in the bottom category prohibited additional stratification by race.

Table 4. ORs for squamous cell esophageal cancer in black and white men according to consumption of vitamin supplements

Factor	White				Black			
	No. of cases[a]	No. of controls[a]	OR[b]	95% CI	No. of cases[a]	No. of controls[a]	OR[b]	95% CI
Never took vitamins	86	414	1.0	-	169	363	1.0	-
Took vitamins	28	262	0.6	0.4-1.1	50	191	0.8	0.5-1.2
Don't know	0	5			0	3		
Took multivitamins	25	209	0.7	0.4-1.2	42	143	0.8	0.5-1.4
Number of years								
<10	13	81	1.1	0.5-2.3	28	87	0.8	0.5-1.5
⩾10	12	124	0.5	0.2-1.1	14	55	0.9	0.4-2.0
Took Vitamin A	2	21	0.6	0.1-2.8	4	19	0.6	0.2-2.0
Took B Vitamins	6	60	0.7	0.3-1.7	7	32	0.5	0.2-1.4
Took Vitamin C	8	125	0.4	0.2-0.9	8	49	0.4	0.2-1.1
Took cod liver oil	0	19	-	-	6	45	0.5	0.2-1.3

[a] Estimates are adjusted for age, area, smoking, and alcohol and relative to risk of 1.0 for subjects who never took vitamins.

In a previous paper,[2] we reported that a substantial amount of the racial difference in esophageal cancer incidence could be explained by the significantly higher risks for blacks versus whites at each level of alcohol and tobacco intake. To test whether differences in nutritional factors between blacks and whites might modify the interaction of race with combined exposure to drinking and smoking, likelihood ratio test statistics for the significance of the interaction term were compared in logistic models with and without selected dietary variables. In our study population, adjustment for consumption of raw fruits and vegetables and other dietary variables did not affect the interaction of race with the alcohol and tobacco-related risks of esophageal cancer at various levels of exposure.

Discussion

A number of studies indicate that dietary factors and nutritional deficiencies contribute to the incidence of esophageal cancer around the world, with the effects appearing most pronounced in certain developing countries (see recent reviews by Cheng and Day[8] and Munoz and Day[9]). Our population-based case-control study was designed to identify dietary and other risk factors for squamous cell esophageal cancer among white and black men in the United States, including factors that may contribute to the much higher incidence reported among black men.

An earlier report from our study indicated that tobacco and alcohol consumption contributes to over 85 percent of squamous cell esophageal cancer in both races, with risks from combined exposures being especially high in black men.[2] The present analyses suggest that in both races dietary factors contribute to risk through protective effects of fruits and vegetables (especially those eaten raw) and vitamin supplements (especially vitamin C) and through excess risks associated with intake of red and processed meat. However, we found no interaction of dietary factors with the risks associated with various levels of smoking and drinking, although the low exposure category was based on few cases. Further, there was no evidence that nutritional factors might explain the higher risks of esophageal cancer among black than white men with similar amounts of exposure to alcohol and tobacco.[2] However, it is difficult to assess the relatively weak effects of dietary factors amidst the potent effects of alcohol and tobacco, particularly when some degree of misclassification of these variables is likely.

Consistent with other case-control studies of squamous cell esophageal cancer in Western and non-Western populations,[8,10,11] we observed a dose-related protective effect with increasing consumption of fruits and vegetables. While the effect of vegetables was seen mainly in whites, the influence of fruits was evident in both races. However, unlike some other studies of esophageal cancer,[12–14] we noted only a weak protective effect for consumption of citrus fruits. In both races, protective effects were primarily associated with intake of raw fruits and vegetables.

Fruits and vegetables contain a variety of substances (e.g., carotenoids, vitamins A, C, and E, fiber, indoles, isothiocyanates) that have potential anticarcinogenic effects.[10,11] Identifying specific constituents of fruits and/or vegetables is difficult, but some clues were suggested from the analysis of specific micronutrients in our study. The effects of vitamins A and C are not entirely clear, since negative gradients were associated with indices derived only from vegetables in white men and only from fruits in black men. In a previous evaluation of dietary patterns in our control population, we found that blacks more often consumed fruits and vegetables high in vitamins A and C than did whites,[4] whereas the present study revealed that white men consumed more raw fruits and vegetables as well as vitamin C supplements than did black men. It has been suggested that a protective effect of vitamin C from vegetables in blacks may be negated by cooking practices such as extended heating of foods in large amounts of water.[4] This explanation is consistent with the reduced risks we observed among blacks as well as whites eating raw vegetables, and with the lower risks associated with use of multivitamin supplements and vitamin C. In addition, a protective effect was suggested for total fiber and fiber from fruit, which resembles findings from a study of squamous cell esophageal cancer among black men residing in a high-risk area of South Carolina.[12]

It is difficult to disentangle the influence of dietary and nutritional factors from the potent effects of alcohol and tobacco on the risk of esophageal cancer. In particular, heavy consumption of alcoholic beverages can interfere with the consumption and utilization of a variety of nutrients,[15,16] while smokers appear to have lower intake of several nutrients including vitamin C than do nonsmokers.[17,18] In addition, tobacco products, some alcoholic beverages, and certain foods are sources of N-nitroso compounds which may elevate the risk of esophageal and gastric cancers.[19] Further, the endogenous formation of N-nitroso compounds may contribute to the development of these tumors, particularly when accompanied by low intake of vitamins C and E, which interfere with the nitrosation process. Whatever the mechanism, it is noteworthy that white men in our study consumed more raw fruits and vegetables as well as vitamin C supplements than did black men, which may partly account for the substantial racial differences in the incidence of esophageal cancer. Alternatively, it is possible that use of vitamin supplements is associated with aspects of low-risk behavior that we did not measure in this study.

The positive trend we observed for dietary cholesterol in blacks most likely reflects the elevated risks among frequent consumers of eggs and meat. Elevated risks associated with animal sources of food have been noted in some other case-control studies of esophageal cancer,[12-14,20] but the mechanisms are unclear. Heterocyclic amines are potent mutagens and animal carcinogens formed during the cooking of meat;[21] their levels increase with rising temperature and duration of cooking, particularly of red meat, with the highest mutagenic activity produced by pan frying, broiling, and barbecuing. In our previous evaluation of dietary habits among control subjects, there was a striking preference among blacks for fried meat.[4] In addition, the higher risks associated with red meat and especially processed meat consumption in blacks versus whites suggest an effect of N-nitroso compounds or their precursors (nitrates and amines), with the nitrosation process accelerated by low levels of micronutrients.[19] Intake of macronutrients (protein, fat, and carbohydrates) and calories was generally similar among cases and controls, although an inverse relation to BMI was noted in accord with other studies of squamous cell cancer of the esophagus.[12,22]

As with any case-control study, we cannot exclude the possibility that our findings were influenced by selection bias due to differences between responders and nonresponders and between those with acceptable and unacceptable responses to the dietary questions; by a sample size too small for detecting low levels of risk; or by play of chance due to the multiple comparisons. However, when demographic and lifestyle characteristics of control subjects with acceptable and unacceptable dietary histories were compared,[4] the two groups were similar. Although we asked about usual adult eating habits (excluding the past five years), it is possible that differential recall between cases and controls may have resulted from recent dietary changes caused by the disease process (e.g., symptomatic cases may have lowered their intake of raw fruits and vegetables which are difficult to swallow).

Despite these limitations, this population-based case-control study identified variations in dietary factors by race, notably raw fruits and vegetables, vitamin C supplements, and red and processed meat. While these factors do not appear to interact with alcohol and/or tobacco to modify risks, they may independently contribute to the five-fold higher incidence of squamous cell esophageal cancer among black compared to white men in the United States.

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Appendix - Individual foods included in each food group

Dairy products: cheese; milk; ice cream.
Bread, grains, and cereal: bread, rolls, or biscuits; cold cereal; hot cereal; rice; spaghetti, macaroni, or noodles.
Meat, poultry, and fish: bacon or sausage; chicken; beef; fish; liver, liverwurst or chopped liver; lunch meats; mixed dish with meat (e.g., chili, pork and beans, spaghetti and meat balls); other pork or ham; stew.
Poultry and fish: chicken; fish.
Red meat: excludes chicken and fish from "Meat, Poultry, and Fish" list.
Processed meats: bacon or sausage; lunch meat; hot dogs; other pork or ham.
Fruits: apples or pears; apricots; bananas; cantaloupe; grapefruit; oranges or tangerines; orange or grapefruit juice; fresh peaches or nectarines; canned peaches; watermelon.
Citrus fruits: grapefruit; oranges or tangerines.
Noncitrus fruits: excludes grapefruit; oranges or tangerines; and orange or grapefruit juice from "Fruits" list.
Apples/pears/bananas: apples or pears; bananas.
Raw fruits: excludes apricots (more likely to be consumed as canned or dried); canned peaches; and orange or grapefruit juice from "Fruits" list.
Vegetables: green string beans or lima beans; red beets; broccoli; cooked cabbage; coleslaw; carrots; cauliflower; southern greens (collards, mustard greens, kale); okra; green peas; black-eyed peas or cow peas; white potatoes; sweet potatoes or yams; raw tomatoes; cooked tomatoes; tomato or V-8 juice; tossed salad; spinach; vegetable soup; mixed vegetables; zucchini or yellow squash.
Cruciferous/Vitamin C-rich vegetables: broccoli; cooked cabbage; coleslaw; cauliflower; southern greens.
Dark green vegetables: broccoli; southern greens; spinach.
Dark yellow vegetables: carrots; mixed vegetables with carrots; sweet potatoes or yams.
Legumes: green peas; black-eyed peas or cow peas; green string beans or lima beans.
Raw vegetables: cole slaw; raw tomatoes; tossed salad.
Raw fruits and vegetables: apples or pears; bananas; cantaloupe; grapefruit; oranges or tangerines; fresh peaches or nectarines; watermelon; cole slaw; raw tomatoes; tossed salad.